Kink Stability with Line Tying

Evstati G. Evstatiev, Gian Luca Delzanno, and John M. Finn, T-15

An important and still open physical problem is the one of solar flares and coronal mass ejections. A related problem is the formation of astrophysical jets. It is thought that the main reason for the stability of the solar loops is the effective anchoring of their footpoints in the much denser and highly conducting layer of the sun, the photosphere. (See Fig. 1.) The magnetic field lines immersed in the photosphere produce a stabilizing effect, line tying. However, for sufficient footpoint twisting, instability is expected to occur in spite of line tying, and the associated magnetic reconnection is thought to be responsible for flares.

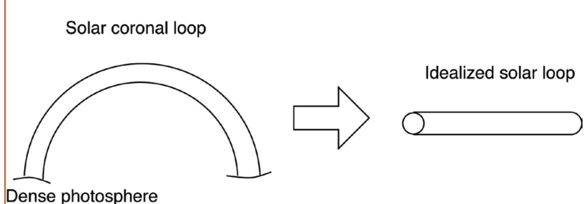

Fig. 1. ***Solar coronal loop and an idealized cylinder model.***

For the study of this problem, experiments as shown in Fig. 2 have been constructed [1, 2]. The curvature of the loop has been neglected because it is of secondary importance for the stability study. The plasma column is created inside the cavity of the device and a strong external axial magnetic field is imposed. Current is run from one end to the other, thus creating poloidal magnetic field. As the current is gradually increased, the poloidal magnetic field increases correspondingly. Past a certain value of the current the plasma column becomes unstable. The main instability is the kink instability—the plasma column bends as in Fig. 3. As the instability develops and becomes nonlinear, the configuration reaches a point where magnetic lines can reconnect and possibly form current sheets, see Fig. 4.

Theoretically the studies to date are either mostly numerical, involve overly simplified models, or only determine sufficient conditions for the instability. We propose a new semianalytical method for linear stability study based on expansion in radial eigenfunctions. Temporarily considering the growth rate γ to be given, the radial eigenfunctions and their corresponding eigenvalues, the axial wavenumbers k, possibly complex, are found. Summing over a small number of eigenfunctions, the value of γ is adjusted until the boundary conditions at the two end conducting plates are satisfied. A strong point of our method is that it allows us to better understand the importance of the individual eigenmodes. It is also computationally more efficient than a two-dimensional code since at each stage only ordinary differential equations are solved.

Linear theory suggests that in an infinitely long cylinder the instability leads to the formation of a current sheet. For a finite length and line-tied boundary conditions, however, it is still an open question whether a current sheet forms or not. Different authors have argued in favor of both. The new method allows a better understanding of how the instability develops and

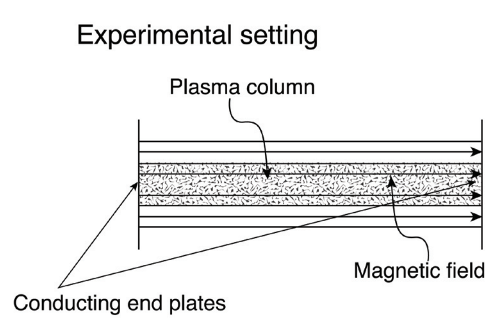

Fig. 2. ***Experiment on stability of a plasma column.***

what are the important regimes that could possibly lead to current sheet formation. The results so far suggest that a long loop will have current sheets where indicated by linear theory, but shorter loops may develop current sheets nonlinearly as the topology of the field changes, see Fig. 4. The issue of development of current sheets in such configurations is generally called the Parker problem.

For more information contact Evstati G. Evstatiev at eevstatiev@lanl.gov.

[1] I. Furno, et al., *Rev. Sci. Instruments* **74,** 2324–2331 (2003).
[2] W.F. Bergerson, et al., *Phys. Rev. Lett.* **96,** 015004/1–4 (2006).

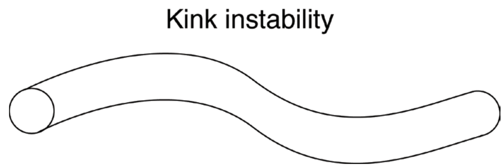

Fig. 3.
Linear stage of the kink instability.

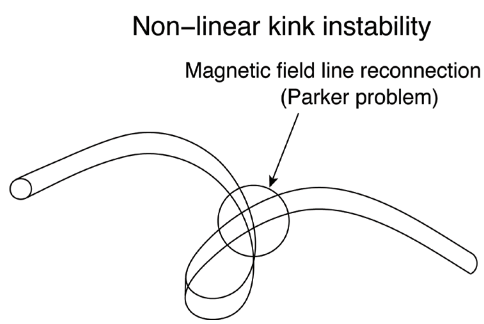

Fig. 4.
Nonlinear stage of the kink instability.